

FINAL REPORT SUBMITTED
TO
TERRY SWALBERG

COPY

REGARDING

THE RE-INVENTORY OF THE LICHEN BIOMONITORING PROGRAM AND BASELINE
FOR

SELECTED SITES IN THE BRIDGER WILDERNESS AREA, BRIDGER-TETON
NATIONAL FOREST, WYOMING

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INTRODUCTION

In accordance with the objectives of our research proposal we are submitting this final report summarizing our lichen air quality biomonitoring work in the Bridger Wilderness Area of the Bridger-Teton National Forest. This report is based on our 1998 field collections. Included in this report is a detailed position description for each reference site, as well as a list of the sensitive indicator species collected for elemental analysis from each site during the summer of 1998. A total of 20 elemental analysis samples were collected along the trails to Hobbs Lake and Big Sandy Lake. The distance along each trail, from the wilderness boundary to the designated end points (Hobbs lake and Big Sandy Lake), was divided into three parts (a beginning segment, a middle segment and a final segment). These divisions correlate with the six reference sites established in July of 1991 (figure 1). The 1998 collections represent the second ongoing evaluation of the baseline since it was originally established in 1983 by Mason Hale. The final report includes elemental analysis data from all three collection periods (1983, 1991 and 1998), as well as a current assessment of the baseline. With the 1998 collections we have expanded the baseline to include additional sensitive indicator species including all or some combination of *Xanthoparmelia cumberlandia*, *Letharia vulpina*, *Usnea subfloridana*, and *Rhizoplaca melanophthalma*. Hales original elemental analysis samples, along the Big Sandy Lake Trail, were limited to specimens of *Xanthoparmelia cumberlandia*. In 1991 we added several species to the elemental analysis list, including *Dermatocarpon miniatum*, *umbilicaria americana*, *Letharia vulpina*, and *Rhizoplaca melanophthalma*; however, two species (*Dermatocarpon miniatum* and *Umbilicaria americana*) showed significant substrate contamination for several pollutant elements, thus giving false high readings for some elements. Those species were not included in our 1998 collections. In reviewing the 1991 samples I realized that several samples (due to cost constraints) had not been analyzed, included in this group are two samples from Hobbs Lake Trail (1-7 *Letharia vulpina*; and 2-8 *Xanthoparmelia cumberlandia*) and two samples from Big Sandy Lake Trail (2-11 *Xanthoparmelia cumberlandia* and 2-12 *Xanthoparmelia cumberlandia*). In order to strengthen the comparison between the 1991 and 1998 sampling periods I have submitted these four 1991 samples for analysis. As soon as the data is available I will revise tables 1 and 2 and submit a modified report. Overall, pollutant element concentrations in 1998 samples were lower than 1991 samples.

REFERENCE SITES: A total of 6 reference sites were established in the Bridger Wilderness Area during the summer of 1991. Elemental analysis samples were collected for re-evaluation of the pollutant element loads in the summer 1998. Specifically, collections were made at the following locations:

Transect #1: 13 August 1998 (13 July 1991). Along trail to Hobbs Lake, Bridger Wilderness Area, Bridger Teton National Forest, Sublette County, Wyoming.

-**At the wilderness boundary** (beginning segment-Hobbs Lake No. 1), GPS reading: 43° 00.192' North Latitude, 109° 43.239' West Longitude; elevation: 9678 feet (2950 meters). Elemental analysis material collected: *Letharia vulpina* (on conifer lignum) and *Usnea subfloridana* (on Whitebark Pine).

-**Midpoint between the wilderness boundary and Hobbs Lake** (middle segment-Hobbs Lake No. 2), between GPS reading: 43° 00.852' North Latitude, 109° 42.076' West Longitude; elevation: 9864 feet (3000 meters); and 43° 01.301' North Latitude, 109° 41.654' West Longitude; elevation: 10006 feet (3050 meters). Elemental analysis material collected: *Letharia vulpina* (on conifer lignum), *Usnea subfloridana* (on conifer lignum and branches), *Rhizoplaca melanophthalma* (on rock), and *Xanthoparmelia cumberlandia* (on rock).

-**Near Hobbs Lake** (endpoint segment-Hobbs Lake No. 3), GPS reading: 43° 02.327' North Latitude, 109° 40.402' West Longitude; elevation: 10,088 feet (3065 meters). Elemental analysis material collected: *Letharia vulpina* (on conifer lignum) and *Xanthoparmelia cumberlandia* (on rock).

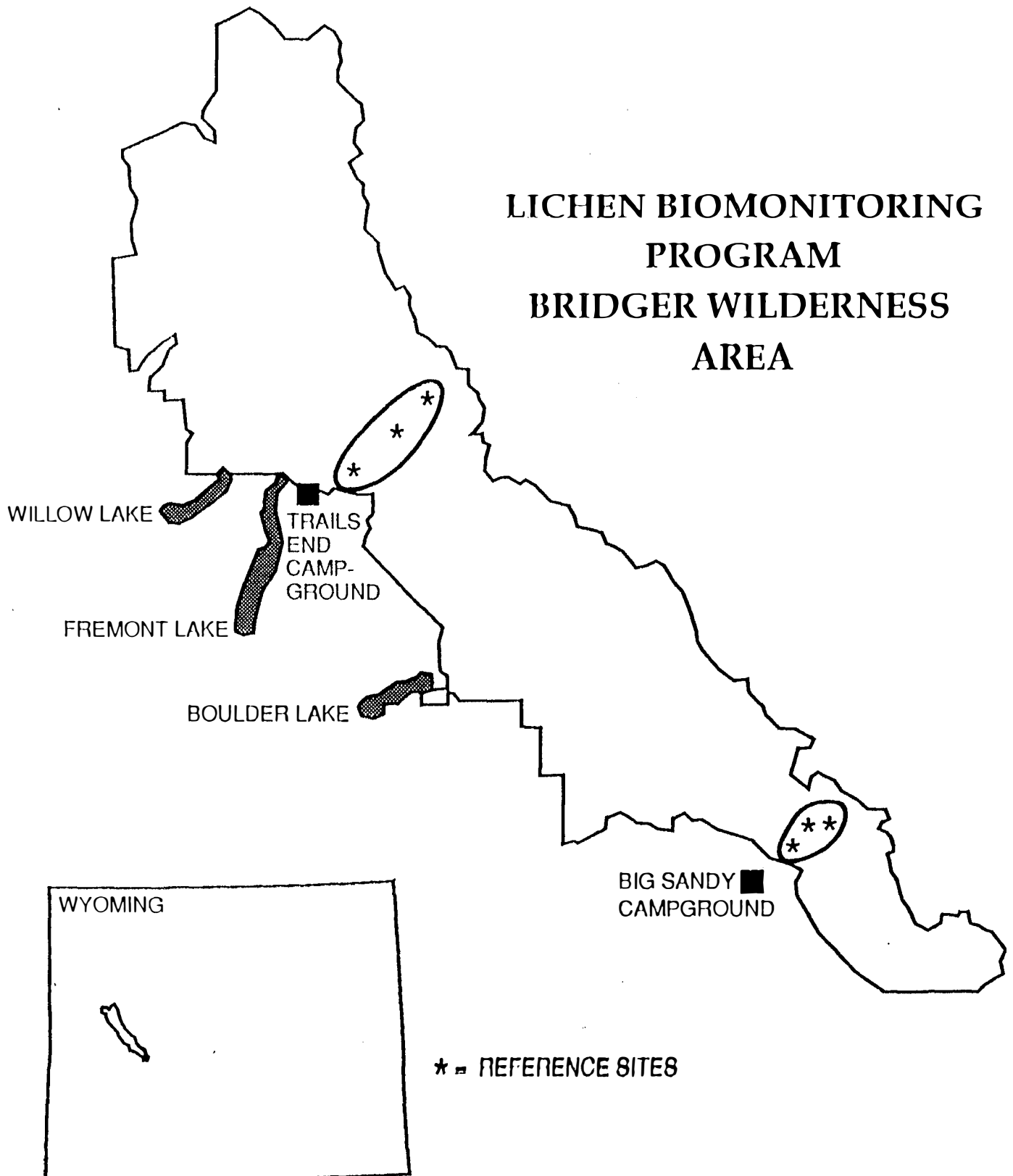
Collectors: Larry L. St. Clair and Lyndon D. Porter.

Transect #2: 14 August 1998 (15 July 1991). Along trail to Big Sandy Lake, Bridger Wilderness Area, Bridger Teton National Forest, Sublette County, Wyoming.

-**Near the wilderness boundary** (beginning segment-Big Sandy Lake No. 1), between GPS reading: 42° 41.795' North Latitude, 109° 15.418' West Longitude; elevation: 9350 feet (2850 meters); and 42° 42.573' North Latitude, 109° 14.714' West Longitude; elevation: 9399 feet

BRIDGER WILDERNESS AREA

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(2865 meters). Elemental analysis material collected: *Letharia vulpina* (on conifer lignum), *Usnea subfloridana* (on Whitebark Pine branches), *Rhizoplaca melanophthalma* (on rock), and *Xanthoparmelia cumberlandia* (on rock).

-Midpoint between the wilderness boundary and Big Sandy Lake (middle segment-Big Sandy Lake No. 2), between GPS reading: 42° 42.573' North Latitude, 109° 14.714' West Longitude; elevation: 9399 feet (2865 meters); and 42° 43.439' North Latitude, 109° 13.909' West Longitude; elevation: 9482 feet (2890 meters). Elemental analysis material collected: *Letharia vulpina* (on conifer lignum), *Usnea subfloridana* (on conifer lignum), *Rhizoplaca melanophthalma* (on rock), and *Xanthoparmelia cumberlandia* (on rock).

-Near Big Sandy Lake (endpoint segment-Big Sandy Lake No. 3), between GPS reading: 42° 43.439' North Latitude, 109° 13.909' West Longitude; elevation: 9482 feet (2890 meters); and 42° 44.143' North Latitude, 109° 12.675' West Longitude; elevation: 9842 feet (3000 meters). Elemental analysis material collected: *Letharia vulpina* (on conifer lignum), *Usnea subfloridana* (on dead conifer twigs), *Rhizoplaca melanophthalma* (on rock), and *Xanthoparmelia cumberlandia* (on rock).

Collectors: Larry L. St. Clair, and Lyndon D. Porter.

STATUS OF COLLECTIONS: Samples of several known sensitive indicator species were collected for elemental analyses. Archival material is currently stored in Nasco Whirlpak plastic bags (to avoid contamination). These samples are permanently housed in the Elemental Analysis Archive Collection at the Herbarium of Nonvascular Cryptogams at Brigham Young University. Sub-samples of all elemental analysis samples were analyzed using Proton Induced X-ray Emission (PIXE) techniques. Concentrations of 23 potential pollutant elements have been determined for each sample.

LICHEN MATERIAL COLLECTED FOR ELEMENTAL ANALYSIS: During the summer of 1998 (August 13-14) a total of 20 samples including four species in four genera from three substrates (rock, lignum, and bark) were collected for elemental analysis. Below is a list of the elemental analysis samples indicating sample number, species, substrate and collection site (the first number represents the storage drawer and the second number indicates the bag number). Reference site numbers correspond to the numbers listed in the site description section of this report.

<u>Sample No.</u>	<u>Taxa</u>	<u>Substrate</u>	<u>Reference Site</u>
52-702	<i>Xanthoparmelia cumberlandia</i>	Rock	Hobbs Lake No.3
52-703	<i>Letharia vulpina</i>	Lignum	Hobbs Lake No.3
52-704	<i>Letharia vulpina</i>	Lignum	Hobbs Lake No.1
52-705	<i>Usnea subfloridana</i>	Bark of Whitebark Pine	Hobbs Lake No.1
52-709	<i>Xanthoparmelia cumberlandia</i>	Rock	Hobbs Lake No.2
52-710	<i>Rhizoplaca melanophthalma</i>	Rock	Hobbs Lake No.2
52-711	<i>Letharia vulpina</i>	Lignum	Hobbs Lake No.2
52-712	<i>Usnea subfloridana</i>	Lignum	Hobbs Lake No.2
52-713	<i>Xanthoparmelia cumberlandia</i>	Rock	Big Sandy Lake No.3
52-714	<i>Letharia vulpina</i>	Lignum	Big Sandy Lake No.3
52-715	<i>Usnea subfloridana</i>	Dead conifer twigs	Big Sandy Lake No.3
52-716	<i>Rhizoplaca melanophthalma</i>	Rock	Big Sandy Lake No.3
52-717	<i>Usnea subfloridana</i>	Lignum	Big Sandy Lake No.2
52-718	<i>Rhizoplaca melanophthalma</i>	Rock	Big Sandy Lake No.2
52-719	<i>Xanthoparmelia cumberlandia</i>	Rock	Big Sandy Lake No.2
52-720	<i>Letharia vulpina</i>	Lignum	Big Sandy Lake No.2
52-721	<i>Letharia vulpina</i>	Lignum	Big Sandy Lake No.1
52-722	<i>Usnea subfloridana</i>	Dead conifer twigs	Big Sandy Lake No.1
52-723	<i>Rhizoplaca melanophthalma</i>	Rock	Big Sandy Lake No.1
52-724	<i>Xanthoparmelia cumberlandia</i>	Rock	Big Sandy Lake No.1

METHODS

COLLECTION OF SENSITIVE INDICATOR SPECIES FOR ELEMENTAL ANALYSES: All elemental analysis samples were collected using a ceramic knife to avoid metal contamination. At each reference site sufficient material of the available sensitive indicator species (all or some combination of *Xanthoparmelia cumberlandia*, *Rhizoplaca melanophthloma*, *Letharia vulpina*, and *Usnea subfloridana*) was collected for elemental analyses (3-6 grams dry weight). All elemental analysis material was placed in Nasco sterile plastic bags (to avoid contamination) and transported back to the BYU Herbarium of Nonvascular Cryptogams. Excess material is permanently stored in Nasco sterile plastic bags in the Archival Collection of Elemental Analysis Samples at the BYU Herbarium of Nonvascular Cryptogams. This material is available for additional testing upon request.

DETERMINATION OF POLLUTANT ELEMENT CONCENTRATIONS IN TISSUES OF SENSITIVE INDICATOR SPECIES: In the herbarium, surface debris and substrate material were removed from all elemental analysis samples. Clean one gram samples of at least one sensitive indicator species from each reference site were then delivered to the Elemental Analysis Laboratory at Brigham Young University.

Samples were prepared for PIXE analysis using the methods of Dufflou et al. (1987). Samples were placed in Teflon containers with a Teflon coated steel ball, cooled to liquid nitrogen temperature, powdered by brittle fracture techniques using a Braun Mikro-Dismemberator II, and then dried in an Imperial IV Microprocessor Oven for 14 hours at 80° C. Sub-samples weighing 150 mg were then placed in Teflon containers and spiked with 1 ml of a 360 ppm Yttrium solution. The samples were then oven dried again for 14 hours at 80° C. Samples were then homogenized using the Mikro-Dismemberator. Approximately 1 mg of powdered lichen tissue was then carefully weighed out onto a thin polycarbonate film in an area of 0.5 cm². A 1.5% solution of polystyrene in toluene was used to secure the sample to the film.

Samples were analyzed using a 2 MV Van de Graaff accelerator with a 2.28 MeV proton beam which passed through a 1.1 mg/cm² pyrolytic graphite diffuser foil. The proton beam was collimated to irradiate an area of 0.38 cm² on the sample. Typically, 10-100 nA proton beam currents were used. X-rays were detected using a Tracor X-ray Spectrometer (model TX-3/48-206) with a 10 mm² by 3 mm thick Si(Li) detector positioned at 90° to the proton beam. Samples were analyzed twice using different X-ray absorbers between the samples and the detector. One was a 49 mg/cm² Mylar absorber with a 0.27 mm² pinhole (2.8% of detector area) backed with a 8.5 mg/cm² Beryllium foil. A 98 mg/cm² Mylar absorber was also used.

To insure adequate quality control, samples of NIST SRM 1571 orchard leaves and other standards were prepared and analyzed using the same protocol.

OBSERVATIONS AND CONCLUSIONS

1. A cursory field review of the lichen flora along the two transects during the 1998 field season indicates that the flora is still diverse and healthy.
1. All substrates (bark, lignum, rock and soil) still support diverse and abundant lichen communities.
3. An abundance of the more pollution sensitive growth forms, especially foliose and fruticose species still suggests minimal air pollution-related impact.
4. The general absence of necrotic and/or bleached thalli also suggests that the lichen flora has not been particularly impacted by air pollution.
5. In comparing elemental analysis data across all three sampling periods (1983, 1991, and 1998) several patterns emerge (tables 1 & 2):
 - a. Between 1983 and 1991, along Big Sandy Lake Trail, concentrations of several elements increased, including lead, zinc, manganese, iron, cobalt, titanium, vanadium, chromium, and strontium. However, as noted in the 1991 report overall concentration of some of these elements are within the range of background concentrations. Except for iron,

TABLE #1: Mean concentrations of potential pollutant elements in sensitive indicator species from air quality biomonitoring reference sites in the Bridger Wilderness Area

Species / Collection Site / Substrate	Elements (ppm except where indicated)											
Hobbs Lake Trail	S%			Cl			K%			Ca%		
	1983	1991	1998	1983	1991	1998	1983	1991	1998	1983	1991	1998
<i>Letharia vulpina</i> , Near wilderness boundary along trail to Hobbs Lake, Sample #704, lignum			0.048			2700			0.25			0.36
<i>Usnea subfloridana</i> , Near wilderness boundary along trail to Hobbs Lake, Sample #705, bark			0.085			1970			0.26			0.31
<i>Letharia vulpina</i> , Middle segment along trail to Hobbs Lake, Sample #711, lignum			0.038			4100			0.27			0.68
<i>Rhizoplaca melanophthalma</i> , Middle segment along trail to Hobbs Lake, Sample #710, rock			0.098			3900			0.36			1.51
<i>Usnea subfloridana</i> , Middle segment along trail to Hobbs Lake, Sample #712, lignum			0.047			350			0.33			0.64
<i>Xanthoparmelia cumberlandia</i> , Middle segment along trail to Hobbs Lake, Sample #709, rock			0.108			1130			0.6			2.4
<i>Letharia vulpina</i> , Vicinity of Hobbs Lake, Sample #6 & #703, lignum		0.106	0.059		330	3000		0.3	0.26		0.55	0.43
<i>Xanthoparmelia cumberlandia</i> , Vicinity of Hobbs Lake, Sample #4 & #702, rock		0.29	0.069		750	930		1.04	0.4		2.07	0.67

TABLE #1: continued
Bridger Wilderness Area

Species / Collection Site / Substrate	Elements (ppm except where indicated)											
Hobbs Lake Trail	Ti			V			Cr			Ni		
	1983	1991	1998	1983	1991	1998	1983	1991	1998	1983	1991	1998
<i>Letharia vulpina</i> , Near wilderness boundary along trail to Hobbs Lake, Sample #704, lignum			40			8			2			1
<i>Usnea subfloridana</i> , Near wilderness boundary along trail to Hobbs Lake, Sample #705, bark			29			4			2			0
<i>Letharia vulpina</i> , Middle segment along trail to Hobbs Lake, Sample #711, lignum			63			8			4			2
<i>Rhizoplaca melanophthalma</i> , Middle segment along trail to Hobbs Lake, Sample #710, rock			350			11			3			4
<i>Usnea subfloridana</i> , Middle segment along trail to Hobbs Lake, Sample #712, lignum			47			9			3			2
<i>Xanthoparmelia cumberlandia</i> , Middle segment along trail to Hobbs Lake, Sample #709, rock			860			16			9			4
<i>Letharia vulpina</i> , Vicinity of Hobbs Lake, Sample #6 & #703, lignum		97	115		3.7	8		28	2		0.52	1
<i>Xanthoparmelia cumberlandia</i> , Vicinity of Hobbs Lake, Sample #4 & #702, rock		870	630		7.1	12		17.3	4		0.24	4

TABLE #1: continued
Bridger Wilderness Area

Species / Collection Site / Substrate	Elements (ppm except where indicated)											
Hobbs Lake Trail	Cu			Zn			Pb			Mn		
	1983	1991	1998	1983	1991	1998	1983	1991	1998	1983	1991	1998
<i>Letharia vulpina</i> , Near wilderness boundary along trail to Hobbs Lake, Sample #704, lignum			2			29			7			105
<i>Usnea subfloridana</i> , Near wilderness boundary along trail to Hobbs Lake, Sample #705, bark			3			26			4			116
<i>Letharia vulpina</i> , Middle segment along trail to Hobbs Lake, Sample #711, lignum			2			32			13			152
<i>Rhizoplaca melanophthalma</i> , Middle segment along trail to Hobbs Lake, Sample #710, rock			8			52			1-4			84
<i>Usnea subfloridana</i> , Middle segment along trail to Hobbs Lake, Sample #712, lignum			3			43			13			220
<i>Xanthoparmelia cumberlandia</i> , Middle segment along trail to Hobbs Lake, Sample #709, rock			14			83			3-4			130
<i>Letharia vulpina</i> , Vicinity of Hobbs Lake, Sample #6 & #703, lignum		6.5	3		33	35		27	23		106	76
<i>Xanthoparmelia cumberlandia</i> , Vicinity of Hobbs Lake, Sample #4 & #702, rock		21	10		163	48		83	305		137	54

TABLE #1: continued
Bridger Wilderness Area

Species / Collection Site / Substrate	Elements (ppm except where indicated)											
Hobbs Lake Trail	Fe			Co			As			Se		
	1983	1991	1998	1983	1991	1998	1983	1991	1998	1983	1991	1998
<i>Letharia vulpina</i> , Near wilderness boundary along trail to Hobbs Lake, Sample #704, lignum			156			26			2			2
<i>Usnea subfloridana</i> , Near wilderness boundary along trail to Hobbs Lake, Sample #705, bark			210			2			1			1
<i>Letharia vulpina</i> , Middle segment along trail to Hobbs Lake, Sample #711, lignum			260			3			4			3
<i>Rhizoplaca melanophthalma</i> , Middle segment along trail to Hobbs Lake, Sample #710, rock			2600			11			4			2
<i>Usnea subfloridana</i> , Middle segment along trail to Hobbs Lake, Sample #712, lignum			340			3			3			2
<i>Xanthoparmelia cumberlandia</i> , Middle segment along trail to Hobbs Lake, Sample #709, rock			5700			30			4			2
<i>Letharia vulpina</i> , Vicinity of Hobbs Lake, Sample #6 & #703, lignum		500	670		1.04	6		1.21	3		1.38	2
<i>Xanthoparmelia cumberlandia</i> , Vicinity of Hobbs Lake, Sample #4 & #702, rock		6500	4100		12	18		4.9	5		1.93	2

TABLE #1: continued
Bridger Wilderness Area

Species / Collection Site / Substrate	Elements (ppm except where indicated)											
Hobbs Lake Trail	Br			Rb			Sr			Al		
	1983	1991	1998	1983	1991	1998	1983	1991	1998	1983	1991	1998
<i>Letharia vulpina</i> , Near wilderness boundary along trail to Hobbs Lake, Sample #704, lignum			5			11			11			120
<i>Usnea subfloridana</i> , Near wilderness boundary along trail to Hobbs Lake, Sample #705, bark			9			5			7			157
<i>Letharia vulpina</i> , Middle segment along trail to Hobbs Lake, Sample #711, lignum			4			6			15			200
<i>Rhizoplaca melanophthalma</i> , Middle segment along trail to Hobbs Lake, Sample #710, rock			5			17			27			1910
<i>Usnea subfloridana</i> , Middle segment along trail to Hobbs Lake, Sample #712, lignum			7			11			23			87
<i>Xanthoparmelia cumberlandia</i> , Middle segment along trail to Hobbs Lake, Sample #709, rock			20			33			56			7100
<i>Letharia vulpina</i> , Vicinity of Hobbs Lake, Sample #6 & #703, lignum		9.3	7		15.7	9		33	13		-	600
<i>Xanthoparmelia cumberlandia</i> , Vicinity of Hobbs Lake, Sample #4 & #702, rock		52	24		62	18		90	37		-	6100

TABLE #1: continued
Bridger Wilderness Area

Species / Collection Site / Substrate	Elements (ppm except where indicated)								
Hobbs Lake Trail	Si			P			Ba		
	1983	1991	1998	1983	1991	1998	1983	1991	1998
<i>Letharia vulpina</i> , Near wilderness boundary along trail to Hobbs Lake, Sample #704, lignum			630			510			39
<i>Usnea subfloridana</i> , Near wilderness boundary along trail to Hobbs Lake, Sample #705, bark			850			480			37
<i>Letharia vulpina</i> , Middle segment along trail to Hobbs Lake, Sample #711, lignum			980			570			59
<i>Rhizoplaca melanophthalma</i> , Middle segment along trail to Hobbs Lake, Sample #710, rock			8100			1290			67
<i>Usnea subfloridana</i> , Middle segment along trail to Hobbs Lake, Sample #712, lignum			1070			680			53
<i>Xanthoparmelia cumberlandia</i> , Middle segment along trail to Hobbs Lake, Sample #709, rock			2900			1820			100
<i>Letharia vulpina</i> , Vicinity of Hobbs Lake, Sample #6 & #703, lignum		-	3100		-	580		-	41
<i>Xanthoparmelia cumberlandia</i> , Vicinity of Hobbs Lake, Sample #4 & #702, rock		-	23000		-	880		-	78

TABLE #2: Mean concentrations of potential pollutant elements in sensitive indicator species from air quality biomonitoring reference sites in the Bridger Wilderness Area

Species / Collection Site / Substrate	Elements (ppm except where indicated)											
Big Sandy Lake Trail	S%			Cl			K%			Ca%		
	1983	1991	1998	1983	1991	1998	1983	1991	1998	1983	1991	1998
<i>Letharia vulpina</i> , Near wild. bndy. along tr. to Big Sandy Lake, Sample #721, lignum			0.04			164			0.187			0.53
<i>Rhizoplaca melanophthalma</i> , Near wild. bndy. along tr. to Big Sandy Lake, Sample #723, rock			0.091			200			0.31			1.34
<i>Usnea subfloridana</i> , Near wild. bndy. along tr. to Big Sandy Lake, Sample #722, dead conifer twigs			0.076			1760			0.36			0.39
<i>Xanthoparmelia cumberlandia</i> , Near wild. bndy. along tr. to Big Sandy Lake, Sample #17/18 & #724, rock	-		0.066	-		2100	0.3311		0.32	1.0871		1.97
<i>Letharia vulpina</i> , Middle segment along trail to Big Sandy Lake, Sample #720, lignum			0.055			1540			0.22			0.52
<i>Rhizoplaca melanophthalma</i> , Middle segment along trail to Big Sandy Lake, Sample #718, rock			0.033			177			0.27			0.56
<i>Usnea subfloridana</i> , Middle segment along trail to Big Sandy Lake, Sample #717, lignum			0.042			210			0.26			0.6
<i>Xanthoparmelia cumberlandia</i> , Middle segment along trail to Big Sandy Lake, Sample #719, rock			0.068			900			0.32			0.89
<i>Letharia vulpina</i> , Vicinity of Big Sandy Lake, Sample #9 & #714, lignum		0.199	0.064		310	2800		0.53	0.22		1.21	0.6
<i>Rhizoplaca melanophthalma</i> , Vicinity of Big Sandy Lake, Sample #10 & #716, rock		0.106	0.062		107	2600		0.44	0.44		0.99	0.33
<i>Usnea subfloridana</i> , Vicinity of Big Sandy Lake, Sample #715, dead conifer twigs			0.068			2600			0.39			0.25
<i>Xanthoparmelia cumberlandia</i> , Vicinity of Big Sandy Lake, Sample #5/6 & #13 & #713, rock	-	0.13	0.043	-	280	2800	0.3308	0.73	0.26	2.2442	3.5	3.4

TABLE #2: continued
Bridger Wilderness Area

Species / Collection Site / Substrate	Elements (ppm except where indicated)											
Big Sandy Lake Trail	Ti			V			Cr			Ni		
	1983	1991	1998	1983	1991	1998	1983	1991	1998	1983	1991	1998
<i>Letharia vulpina</i> , Near wild. bndy. along tr. to Big Sandy Lake, Sample #721, lignum			40			5			2			1
<i>Rhizoplaca melanophthalma</i> , Near wild. bndy. along tr. to Big Sandy Lake, Sample #723, rock			220			8			3			2
<i>Usnea subfloridana</i> , Near wild. bndy. along tr. to Big Sandy Lake, Sample #722, dead conifer twigs			28			5			1			1
<i>Xanthoparmelia cumberlandia</i> , Near wild. bndy. along tr. to Big Sandy Lake, Sample #17/18 & #724, rock	482		460	17.4		10	5.7		4	4.4		4
<i>Letharia vulpina</i> , Middle segment along trail to Big Sandy Lake, Sample #720, lignum			71			5			2			1
<i>Rhizoplaca melanophthalma</i> , Middle segment along trail to Big Sandy Lake, Sample #718, rock			57			6			2			1
<i>Usnea subfloridana</i> , Middle segment along trail to Big Sandy Lake, Sample #717, lignum			69			6			2			1
<i>Xanthoparmelia cumberlandia</i> , Middle segment along trail to Big Sandy Lake, Sample #719, rock			550			12			6			3
<i>Letharia vulpina</i> , Vicinity of Big Sandy Lake, Sample #9 & #714, lignum		260	88		6.1	7		4.5	2		2.8	1
<i>Rhizoplaca melanophthalma</i> , Vicinity of Big Sandy Lake, Sample #10 & #716, rock		380	500		8.5	12		5.7	5		2.2	3
<i>Usnea subfloridana</i> , Vicinity of Big Sandy Lake, Sample #715, dead conifer twigs			34			6			2			1
<i>Xanthoparmelia cumberlandia</i> , Vicinity of Big Sandy Lake, Sample #5/6 & #13 & #713, rock	359	1160	230	15.7	30	10	5.6	22	4	4.9	0.23	2

TABLE #2: continued
Bridger Wilderness Area

Species / Collection Site / Substrate	Elements (ppm except where indicated)											
Big Sandy Lake Trail	Cu			Zn			Pb			Mn		
	1983	1991	1998	1983	1991	1998	1983	1991	1998	1983	1991	1998
<i>Letharia vulpina</i> , Near wild. bndy. along tr. to Big Sandy Lake, Sample #721, lignum			2			26			12			61
<i>Rhizoplaca melanophthalma</i> , Near wild. bndy. along tr. to Big Sandy Lake, Sample #723, rock			6			43			11			36
<i>Usnea subfloridana</i> , Near wild. bndy. along tr. to Big Sandy Lake, Sample #722, dead conifer twigs			3			37			7			52
<i>Xanthoparmelia cumberlandia</i> , Near wild. bndy. along tr. to Big Sandy Lake, Sample #17/18 & #724, rock	31.7		11	58.8		35	46.1		42	117.2		56
<i>Letharia vulpina</i> , Middle segment along trail to Big Sandy Lake, Sample #720, lignum			2			29			8			51
<i>Rhizoplaca melanophthalma</i> , Middle segment along trail to Big Sandy Lake, Sample #718, rock			2			38			12			88
<i>Usnea subfloridana</i> , Middle segment along trail to Big Sandy Lake, Sample #717, lignum			2			38			7			94
<i>Xanthoparmelia cumberlandia</i> , Middle segment along trail to Big Sandy Lake, Sample #719, rock			10			48			39			66
<i>Letharia vulpina</i> , Vicinity of Big Sandy Lake, Sample #9 & #714, lignum		13	3		48	28		47	14		100	44
<i>Rhizoplaca melanophthalma</i> , Vicinity of Big Sandy Lake, Sample #10 & #716, rock		17.9	6		39	32		40	10		59	40
<i>Usnea subfloridana</i> , Vicinity of Big Sandy Lake, Sample #715, dead conifer twigs			3			30			4			80
<i>Xanthoparmelia cumberlandia</i> , Vicinity of Big Sandy Lake, Sample #5/6 & #13 & #713, rock	35.6	35	4	74.8	146	39	102.7	145	16	89	170	51

TABLE #2: continued
Bridger Wilderness Area

Species / Collection Site / Substrate	Elements (ppm except where indicated)											
Big Sandy Lake Trail	Fe			Co			As			Se		
	1983	1991	1998	1983	1991	1998	1983	1991	1998	1983	1991	1998
<i>Letharia vulpina</i> , Near wild. bndy. along tr. to Big Sandy Lake, Sample #721, lignum			230			2			2			2
<i>Rhizoplaca melanophthalma</i> , Near wild. bndy. along tr. to Big Sandy Lake, Sample #723, rock			2100			9			4			2
<i>Usnea subfloridana</i> , Near wild. bndy. along tr. to Big Sandy Lake, Sample #722, dead conifer twigs			186			2			2			2
<i>Xanthoparmelia cumberlandia</i> , Near wild. bndy. along tr. to Big Sandy Lake, Sample #17/18 & #724, rock	5293		3100	<0.33		13	-		4	-		2
<i>Letharia vulpina</i> , Middle segment along trail to Big Sandy Lake, Sample #720, lignum			380			3			2			1
<i>Rhizoplaca melanophthalma</i> , Middle segment along trail to Big Sandy Lake, Sample #718, rock			430			3			2			2
<i>Usnea subfloridana</i> , Middle segment along trail to Big Sandy Lake, Sample #717, lignum			440			3			2			2
<i>Xanthoparmelia cumberlandia</i> , Middle segment along trail to Big Sandy Lake, Sample #719, rock			4200			16			4			2
<i>Letharia vulpina</i> , Vicinity of Big Sandy Lake, Sample #9 & #714, lignum		1600	490		2	15		4	3		1.35	2
<i>Rhizoplaca melanophthalma</i> , Vicinity of Big Sandy Lake, Sample #10 & #716, rock		2800	3200		8.4	26		0.71	3		0.61	1
<i>Usnea subfloridana</i> , Vicinity of Big Sandy Lake, Sample #715, dead conifer twigs			270			16			1			1
<i>Xanthoparmelia cumberlandia</i> , Vicinity of Big Sandy Lake, Sample #5/6 & #13 & #713, rock	4634	8600	1950	<0.33	25	9	-	6.8	3	-	1.7	2

TABLE #2: continued
Bridger Wilderness Area

Species / Collection Site / Substrate	Elements (ppm except where indicated)											
Big Sandy Lake Trail	Br			Rb			Sr			Al		
	1983	1991	1998	1983	1991	1998	1983	1991	1998	1983	1991	1998
<i>Letharia vulpina</i> , Near wild. bndy. along tr. to Big Sandy Lake, Sample #721, lignum			4			4			13			119
<i>Rhizoplaca melanophthalma</i> , Near wild. bndy. along tr. to Big Sandy Lake, Sample #723, rock			3			8			76			2300
<i>Usnea subfloridana</i> , Near wild. bndy. along tr. to Big Sandy Lake, Sample #722, dead conifer twigs			4			6			11			129
<i>Xanthoparmelia cumberlandia</i> , Near wild. bndy. along tr. to Big Sandy Lake, Sample #17/18 & #724, rock	-		19	-		13	17.4		40	4289		3000
<i>Letharia vulpina</i> , Middle segment along trail to Big Sandy Lake, Sample #720, lignum			5			3			14			320
<i>Rhizoplaca melanophthalma</i> , Middle segment along trail to Big Sandy Lake, Sample #718, rock			4			3			20			125
<i>Usnea subfloridana</i> , Middle segment along trail to Big Sandy Lake, Sample #717, lignum			5			5			19			250
<i>Xanthoparmelia cumberlandia</i> , Middle segment along trail to Big Sandy Lake, Sample #719, rock			24			13			39			4600
<i>Letharia vulpina</i> , Vicinity of Big Sandy Lake, Sample #9 & #714, lignum		15.6	5		16	5		50	16		-	310
<i>Rhizoplaca melanophthalma</i> , Vicinity of Big Sandy Lake, Sample #10 & #716, rock		7.9	2		21	25		86	48		-	3800
<i>Usnea subfloridana</i> , Vicinity of Big Sandy Lake, Sample #715, dead conifer twigs			6			5			15			148
<i>Xanthoparmelia cumberlandia</i> , Vicinity of Big Sandy Lake, Sample #5/6 & #13 & #713, rock	-	53	14	-	58	13	26.6	122	60	5809	-	1540

TABLE #2: continued
Bridger Wilderness Area

Species / Collection Site / Substrate	Elements (ppm except where indicated)								
Big Sandy Lake Trail	Si			P			Ba		
	1983	1991	1998	1983	1991	1998	1983	1991	1998
<i>Letharia vulpina</i> , Near wild. bndy. along tr. to Big Sandy Lake, Sample #721, lignum			880			360			37
<i>Rhizoplaca melanophthalma</i> , Near wild. bndy. along tr. to Big Sandy Lake, Sample #723, rock			7700			920			58
<i>Usnea subfloridana</i> , Near wild. bndy. along tr. to Big Sandy Lake, Sample #722, dead conifer twigs			670			670			33
<i>Xanthoparmelia cumberlandia</i> , Near wild. bndy. along tr. to Big Sandy Lake, Sample #17/18 & #724, rock	-		11600	993		930	81.8		61
<i>Letharia vulpina</i> , Middle segment along trail to Big Sandy Lake, Sample #720, lignum			1550			520			32
<i>Rhizoplaca melanophthalma</i> , Middle segment along trail to Big Sandy Lake, Sample #718, rock			1190			570			35
<i>Usnea subfloridana</i> , Middle segment along trail to Big Sandy Lake, Sample #717, lignum			1450			700			36
<i>Xanthoparmelia cumberlandia</i> , Middle segment along trail to Big Sandy Lake, Sample #719, rock			16200			870			82
<i>Letharia vulpina</i> , Vicinity of Big Sandy Lake, Sample #9 & #714, lignum		-	1670		-	420		-	35
<i>Rhizoplaca melanophthalma</i> , Vicinity of Big Sandy Lake, Sample #10 & #716, rock		-	14500		-	600		-	134
<i>Usnea subfloridana</i> , Vicinity of Big Sandy Lake, Sample #715, dead conifer twigs			880			670			35
<i>Xanthoparmelia cumberlandia</i> , Vicinity of Big Sandy Lake, Sample #5/6 & #13 & #713, rock	-	-	7100	1297	-	900	49.4	-	70

- manganese, lead, chromium, cobalt, vanadium, and titanium which were slightly to moderately elevated (figure 2).
- b. Baseline data for two particularly important elements begin with the 1991 collections, namely sulfur and arsenic. It was noted in 1991 that two samples (2-9 *Letharia vulpina*, Sandy Lake Trail and 1-4 *Xanthoparmelia cumberlandia*, Hobbs Lake Trail) had high sulfur concentrations (0.199% and 0.29% respectively). In addition three samples showed elevated levels of arsenic (2-9 *Letharia vulpina* and 2-13 *Xanthoparmelia cumberlandia*, from Big Sandy Lake Trail, and 1-4 *Xanthoparmelia cumberlandia*, from Hobbs Lake Trail).
 - c. The 1998 data set shows several promising trends:
 - i. All sulfur concentrations are well below the 0.20% threshold level. Even the two species showing high levels in 1991 (samples 2-9 and 1-4) have much reduced loads in 1998 (samples 52-714 and 52-702).
 - ii. Generally, chromium, zinc, lead, manganese, titanium, iron, strontium, and arsenic levels are lower.
 - iii. All zinc-copper ratios reflect typical crustal concentrations for these elements (anything above 2 reflects background concentrations for these elements)..
 - iv. Generally, iron-titanium ratios reflect typical crustal concentrations for these elements except for two samples from Big Sandy Lake Trail (52-723 *Rhizoplaca melanophthalma* and 52-713 *Xanthoparmelia cumberlandia*) which show elevated iron concentrations with iron-titanium ratios of 9.55 and 8.48 respectively (anything less than 7.5 reflects background concentrations for these two elements)..
 - v. All nickel concentrations are well within background levels; however, four out of six samples show some increase between 1991 and 1998.
 - d. One area of concern is the general increase in cobalt concentrations between 1991 and 1998.

RECOMMENDATIONS

1. Eventually, additional reference sites should be established in other parts of the wilderness area. I recommend at least 2-3 additional sites.
2. Sensitive indicator species samples from all sites should be analyzed again in 5-8 years. Comparison of these data over time represents the quickest and most accurate way to track air pollution-related problems.

Fig. 2 Lichen Biomonitoring Program and Baseline

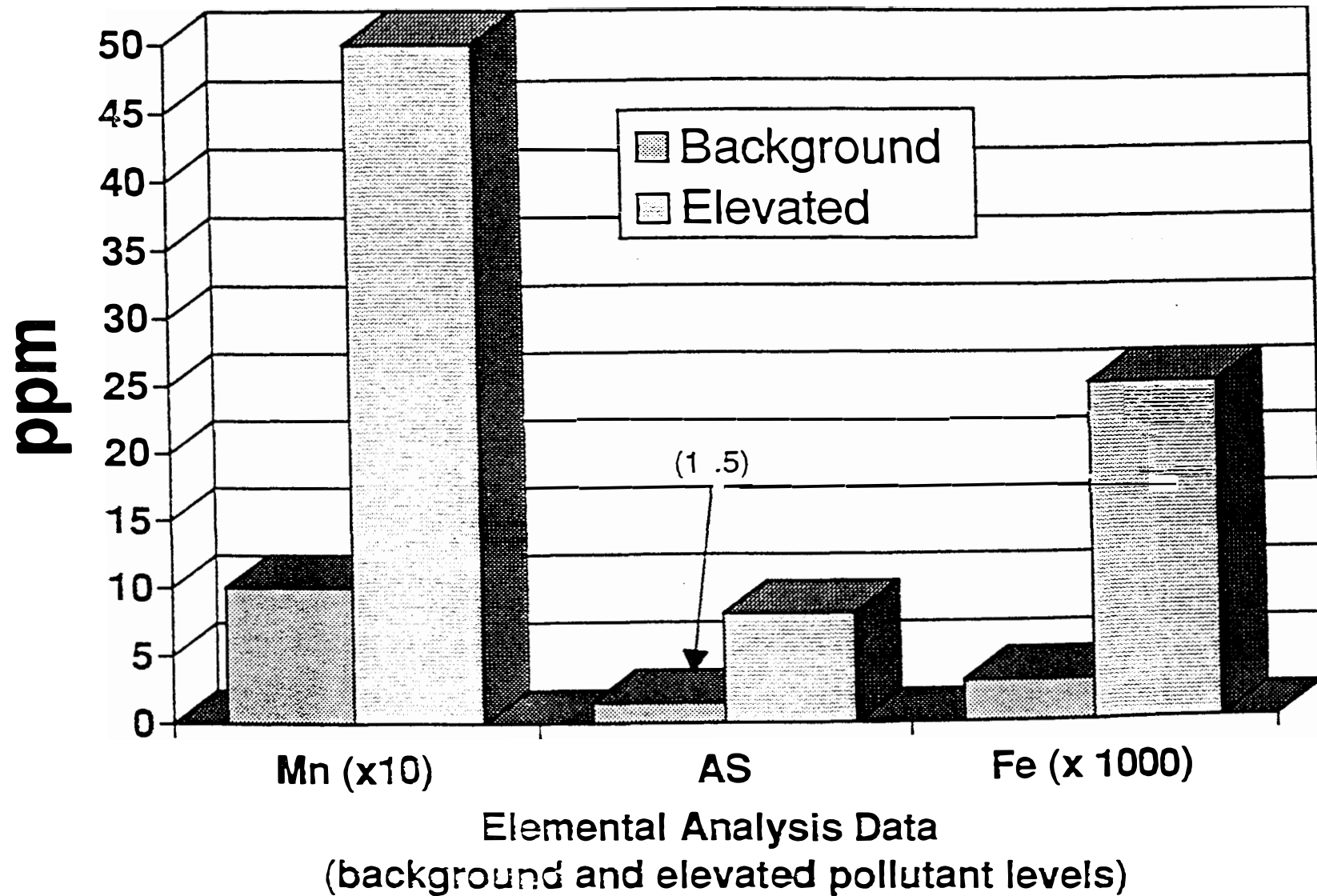
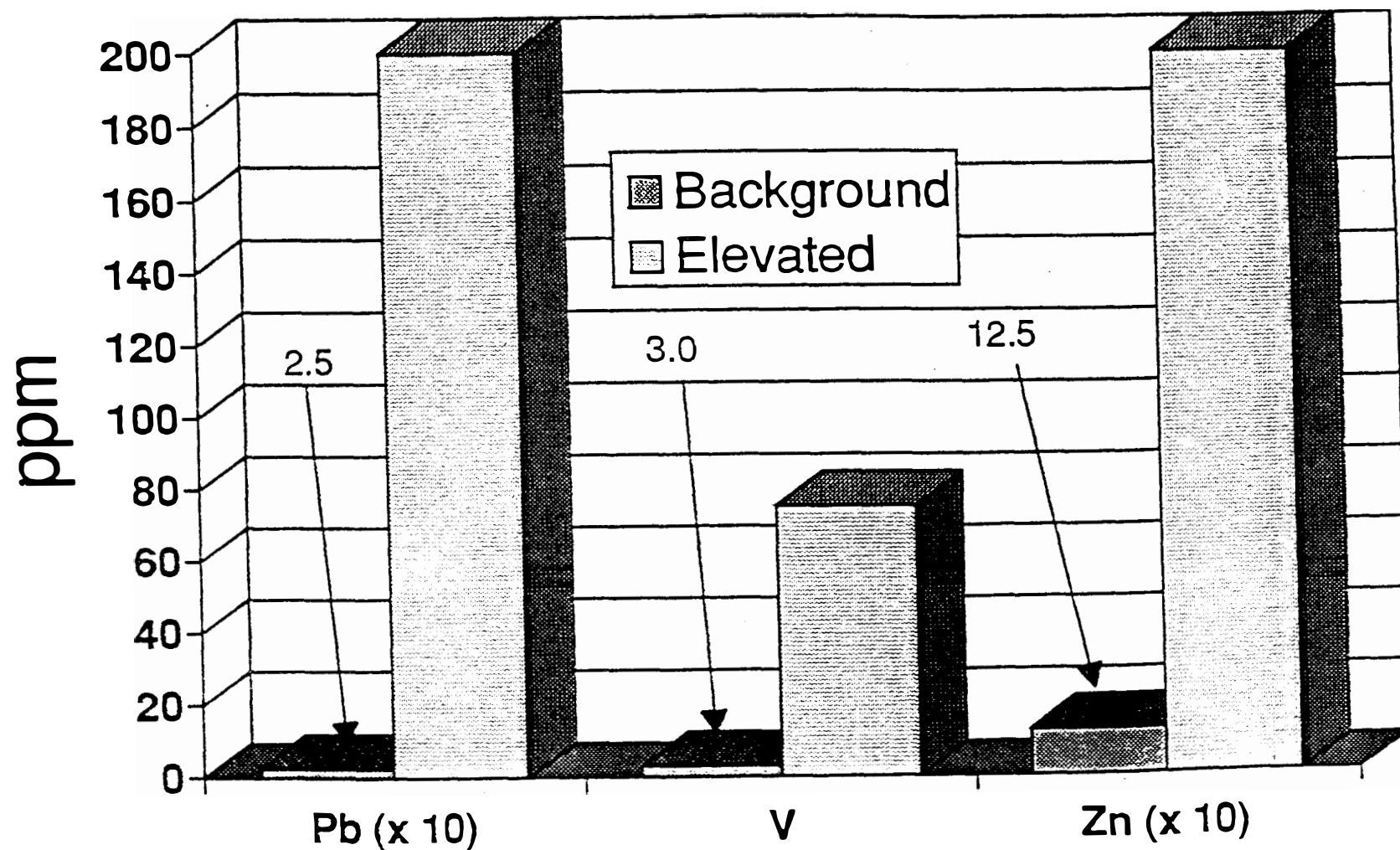


Fig. 2 cont. Lichen Biomonitoring Program and Baseline



Elemental Analysis Data
(background and elevated pollutant levels)

Fig. 2 cont. Lichen Biomonitoring Program and Baseline

